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Final Report

Cost and Schedule Analytical Techniques Development

Contract NAS 8-40431

December 6, 1995

SAIC
6725 Odyssey Drive
Huntsville, AL 35814-1220

Prepared for:
National Aeronautics and Space Adiministration
George C. Marshall Space Flight Center
Engineering Cost Office
Marshall Space Flight Center, AL 35812

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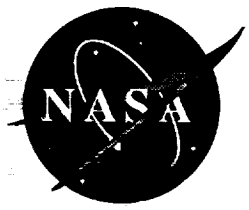

Final Report

Cost and Schedule Analytical Techniques Development
Contract NAS8-40431, Base Year
December 1, 1994 through November 30, 1995

I. INTRODUCTION

This Final Report summarizes the activities performed by Science Applications International Corporation (SAIC) under contract NAS8-40431 "Cost and Schedule Analytical Techniques Development" (CSATD) for the base contract year from December 1, 1994 through November 30, 1995. The Final Report is in compliance with Paragraph 5 of Section F of the contract.

This CSATD contract provides technical services and products to the NASA Marshall Space Flight Center's (MSFC) Engineering Cost Office (PPO3) and the Program Plans and Requirements Office (PPO2). Detailed Monthly Progress Reports were submitted to MSFC in accordance with the contract's Statement of Work Section IV "Reporting and Documentation". These reports spelled out each month's specific work accomplishments, deliverables submitted, major meetings held, and other pertinent information. This Final Report will summarize these activities at a higher level.

II. MSFC TASKS

The basic CSATD contract calls out three major Statement of Work task areas that provide analytical technique developments for MSFC. Accomplishments under these areas are discussed in the following paragraphs.

II. 1. REDSTAR Data Base System Maintenance & Expansion

Approximately 1,300 documents were added to REDSTAR this year, bringing REDSTAR's total holdings to over 17,000. As can be seen in Figure 1 below, the overall growth for REDSTAR over the past four years has been substantial.

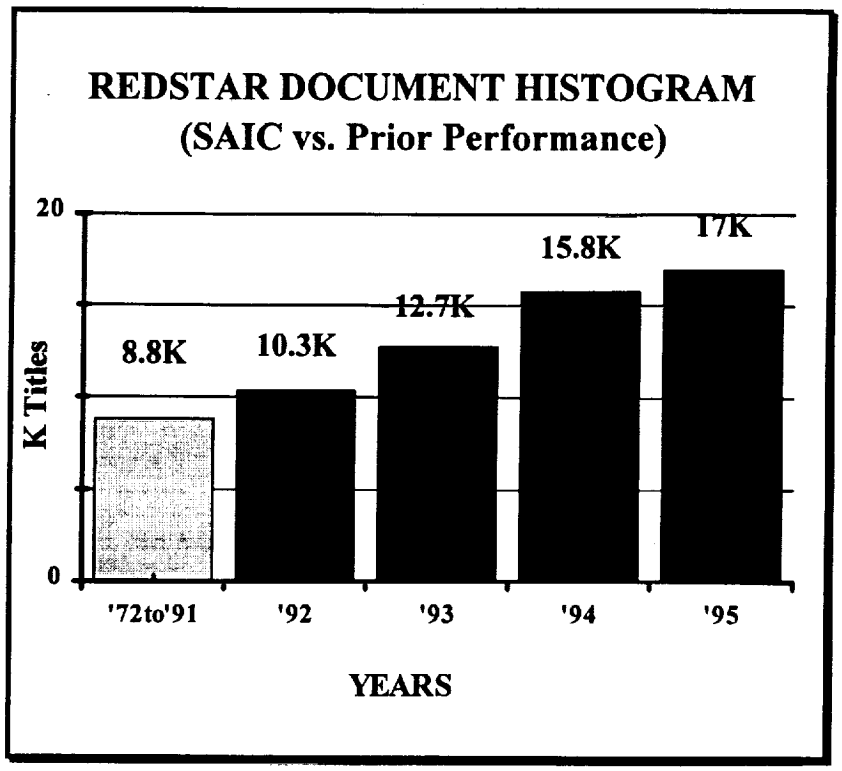

Figure 1 REDSTAR Growth Over the Past Four Years

REDSTAR's growth was mainly due to the receipt of the following: five boxes of reports from MSFC/PP03, eight boxes of schedule data from MSFC/PP02, one box of documents from NASA HQ, twenty-two boxes of data from the JSC Cost Library (totaling 257 new documents), and Shuttle and Saturn V reports from MSFC Comptroller's office.

The following reference tools were purchased: *Jane's 1994/95 All the World's Aircraft, World Aviation Directory, 1995 Van Nostrand's Scientific Encyclopedia, Jane's 1995/96 Space Directory*, and *International Reference Guide to Space Launch Systems.*

The Schedules, Manned, Unmanned, and Launch Vehicle special collections were expanded for the complexity generator effort, and the CD-ROM scanning effort. A collection of Space Station documents, consisting of over 600 documents received from MSFC and NASA HQ, was cataloged into REDSTAR. Also, a Lessons Learned Collection was established which includes sixty seven documents and a complete NASA-Recon bibliography with hundreds of citations. The NASA/DOD translator at the Redstone Scientific Information Center was requested to translate the French report "Performance - Cost Analysis of a Large Program: The Case of Ariane". This is a large report and the translation is partially complete at this time.

Data collection contacts made during the contract year were: Air University, Aerojet Electronics Systems Division, NASP Technology Library located in the MSFC

Advanced Transportation Technology Office, Air Force Space Command, MSFC Gravity Probe-B Project Office, Kelly Air Force Base, Dr. James Van Allen of University of Iowa, Art Azarbarzin of GSFC TOMS-EP Project Office, John Catena of the GSFC SMEX Project Office, Orbital Sciences Corporation, NOAA Public Affairs, John Mankins of NASA HQ on technology readiness levels, JPL Archives Department, Cincinnati University Aerospace Engineering Department on SAFER, NASA HQ Procurement Office, Rockwell International Inspector Project Office, and Calspan/SRL Nanosat Project Office.

Research was conducted to locate information on the following subjects: Special Sensor Microwave Imager/Sounder, examples of cost reductions within on-going NASA programs, Ariane Vulcan engine, Lunar exploration, Manned Mars missions, EHF satellites, cycling stations, Crystal Growth Furnace, passive microwave instruments, several microgravity experiments, NLS operations and manufacturing cost cutting measures, economic benefits of space technology, HETE, FUSE, Bus-1, SAMPEX, Energia launch vehicle, Ariane Automated Transfer Vehicle, Mars Pathfinder, MicroStar, SWAS, REX, RADCAL, Hawkeye-1, FAST, TOMS-EP, SCIFER, POLAR, WIND, SEDS, composite materials, Keck Telescope, hybrid engines, outsourcing, Access-to-Space, cost-benefit analysis, SAFER propulsive backpack, Cassini, aircraft schedules, Nanosat, Inspector, radar and laser cost models.

Expansion of the NASCOM Data Base has been primarily in the area of "cheaper, faster, better" spacecraft. For a data point to be added to NASCOM, the data collection effort has to provide a comprehensive history of the project's cost, technical, and programmatic metrics. In the area of low-cost satellites we have added to the NASCOM Data Base: SAMPEX, SWAS, FAST, HETE, Alexis, MSTI, SME, and Hawkeye. Other additions include UFO and Mars Observer, bringing the total of NASCOM data points to 100. Other data collected in sufficient detail to be added to NASCOM in the coming year include: 4 fighter aircraft, 2 research aircraft, DC-X, recurring cost for Titan IV and Pegasus and actual cost through CDR for AXAF.

To provide continued innovative costing techniques, the entire NASCOM Data Base has been re-normalized during the year. This re-normalization will allow the user more flexibility when estimating System Test Hardware, and items such as Launch and On-orbit Support, and Integration and Test for the entire spacecraft system including payload and launch vehicle integration.

II. 2. Development of Cost Estimating Techniques

The most significant effort completed this year in the area of cost estimating techniques has been the release of the first two versions of the NASA Cost Model (NASCOM). NASCOM is a comprehensive data base and cost model that is used to parametrically estimate the cost of future aerospace hardware. This concept of this model was originally conceived nearly five years ago but was not realized until the release of NASCOM 3.0 in April 1995.

The NASCOM Cost Model operates in the Microsoft Windows environment and has many capabilities that allow the user to develop a thorough and quick estimate. The features include: (1) an online data base with subsystem and component level cost for Manned Spacecraft, Unmanned Earth Orbiting and Planetary Spacecraft, and Launch Vehicles and Engines; (2) the capability to search and filter the data base on over 100 cost, technical, and programatic parameters; (3) the capability to define test hardware, learning curves, complexity factors, and quantities for each cost estimating relationship; (4) the automatic calculation of the system integration elements; and (5) an online documentation and help system that includes a WBS Dictionary and Spacecraft Resumes for each program in the data base.

The NASCOM Cost Model Version 4.0 was released in October 1995. This model, shown in Figure 2, included a data base that was updated to include several new data points and normalization changes.

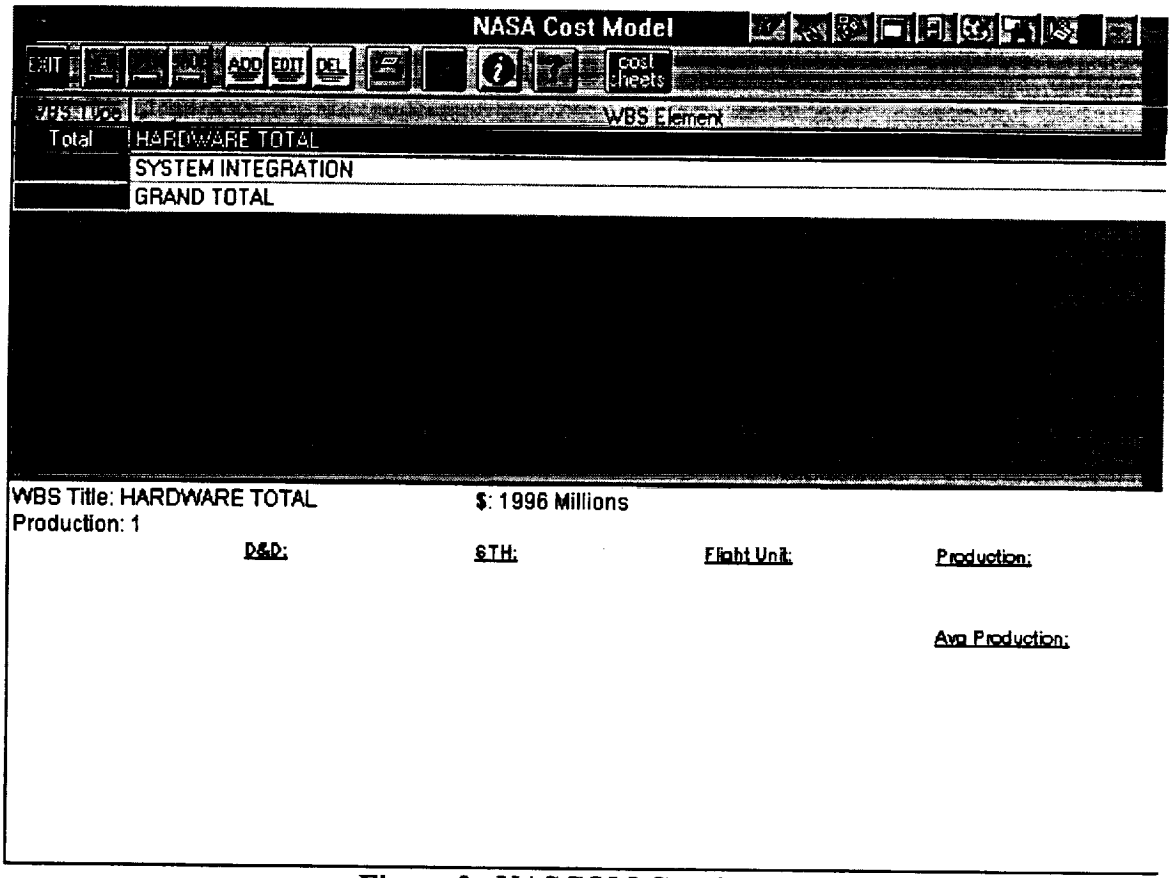

Figure 2 NASCOM Cost Model

NASCOM Version 4.0 also included an updated data level screen that has four levels of data: Group, Subsystem, Component, and Unit. The data level screen was also updated to be more compatible with the Air Force hardware WBS. The updated Data Level screen is shown in Figure 3.

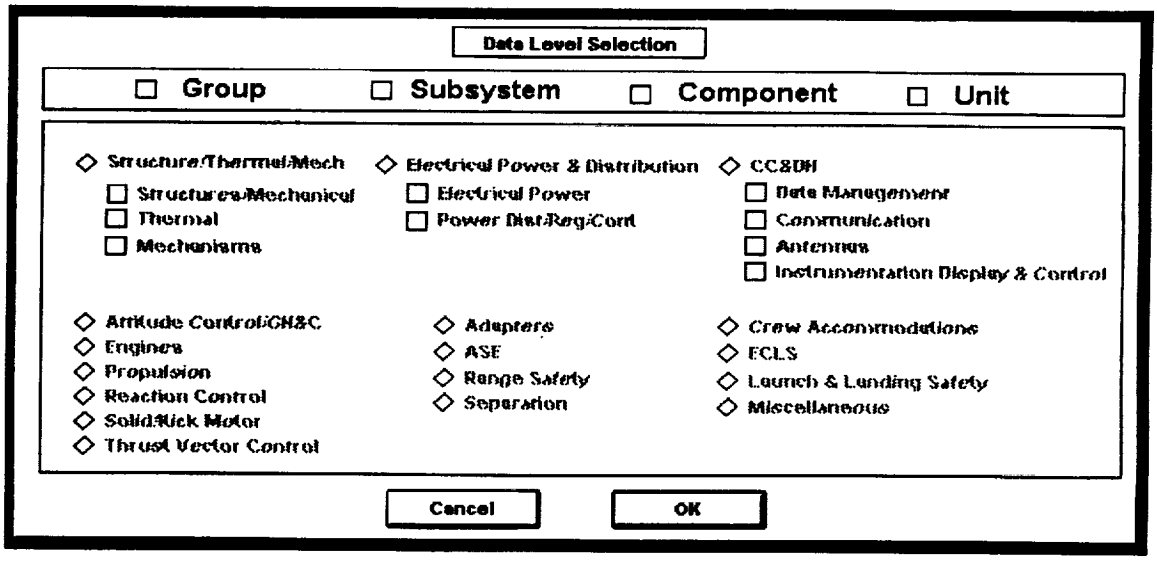

Figure 3 NASCOM Data Level Screen

One other key element that was added to NASCOM in Version 4.0 was the inclusion of a cost sheet viewing module. This module allow the user of NASCOM to view, copy, or print the total cost summary of any single project. Using the standard NASCOM Cost Model data search routines you can only view the cost of project by subsystem or component. This module gives a very powerful new tool to the user and is shown in Figure 4.

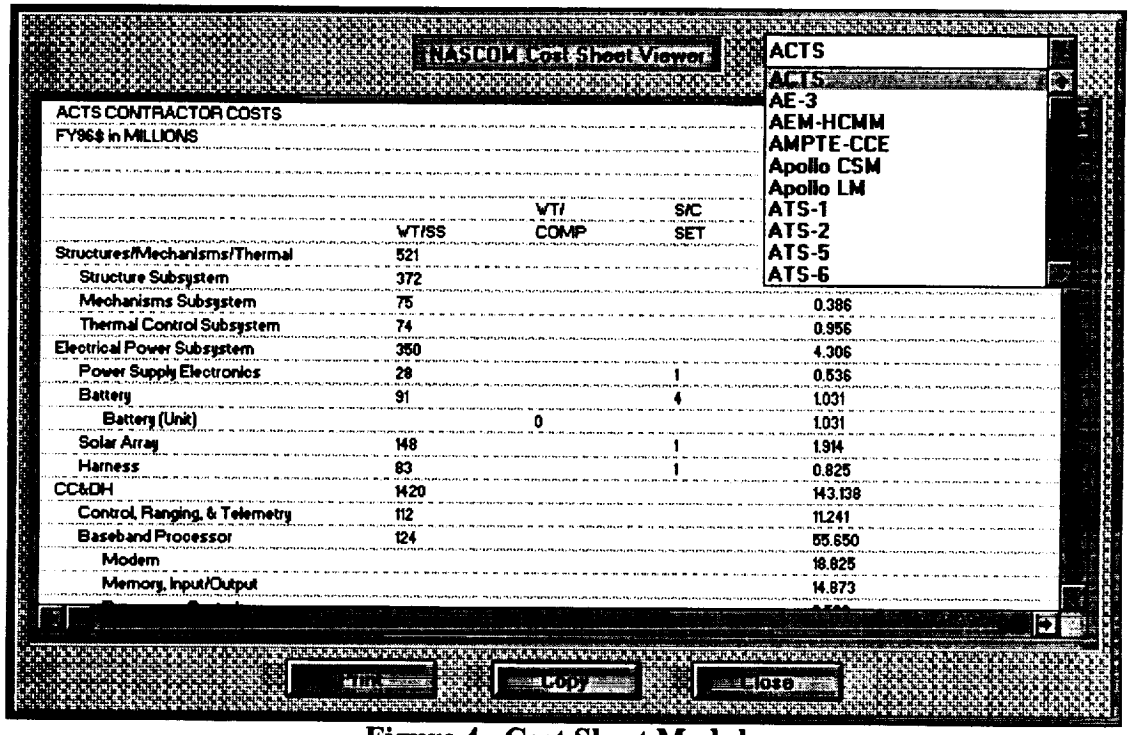

Figure 4 Cost Sheet Module

II. 3. Development of Schedule Plans and Requirements

In December 1994, SAIC delivered a beta version of SACOM (Schedule and Cost Optimization Model) to MSFC. A version 1.0 with the User's Guide was delivered in April. SAIC conducted 5 training classes on the model for NASA personnel in May and June, and a version 1.2 was completed and delivered in June. Currently, the SACOM is fully operational and will be used to integrate schedule analysis with the NASCOM in late 1996.

In January we began a comprehensive search for schedules in the REDSTAR. The task was to examine documents in the library for schedules that may be useful for our analysis. This task has had a lessor priority due to other pressing tasks; however, to date over 200 documents have been tagged that previously were not identified in the computer index as having schedule data.

A number of regressions on various NASA missions were performed in order to determine whether or not there was evidence of a positive relationship between weight and schedule duration. The results were inconclusive for the particular data set examined. In most cases there was no relationship or the slope was negative. Therefore, we made the decision to suspend work on this task and redirect our TER efforts.

A separate file in the REDSTAR for items relating to lessons learned has been established. We have located a number of documents and will continue to add lessons learned documents as they come in to REDSTAR.

This past year we made a number of enhancements to the STEM (Schedule Template Evaluation Model). Five schedule templates have been added to the model: Small Spacecraft Bus template, DOD Aircraft templates, Commercial Aircraft template, Reusable Nuclear Shuttle template, and an X-Plane template. Also added were an on-screen glossary of terms and abbreviations, additional data screens with more information, and several functional changes to make STEM easier to use.

STEM was made compatible with the latest version of Excel. This makes STEM transportable, allows STEM to be given to other potential users, and enables it to be used with the MSFC file server.

SAIC researched and developed a handbook for PP02 that contains guidelines and responsibilities for PPO2 personnel. This document titled "Program Plans and Requirements Office Contributions to the Programs/Projects Assigned to the George C. Marshall Space Flight Center" was delivered to MSFC on August 30.

In addition to the above, we provided support to PP02 on an as needed basis. This includes data searches on such systems as Instruments, Hybrid Propulsion Rocket

Engines, and small telescopes among others. We also plotted the World Launches/Long Range Planning Schedule on several occasions on the SAIC oversized plotter.

III. ADDITIONAL TASKING

In addition to the mainline tasks accomplished for the Program Development directorate of MSFC, several in-scope tasks were performed under the contract for other NASA elements. Those tasks that were funded by the NASA Headquarters Comptroller Office were (1) the enhancement of the Ground Operations Cost Model for the Kennedy Space Center (KSC), (2) the initial phase of an effort to develop comprehensive NASA Operations Cost Models, (3) the transfer of selected REDSTAR Data Base documentation to CD-ROM format and distribute them to NASA centers, and (4) the calibration of the PRICE Systems Cost Model for NASA users. These tasks began on March 31, 1995 and will extend until January 31, 1996 in the Option Year 1 contract.

A task to provide cost estimating and modeling capability at the Ames Research Center was funded jointly by that center and the NASA Comptroller and began on March 31, 1995. It is a one year task and will end on March 30, 1996 in the Option Year 1 contract. A very small task was added on August 11, 1995 to provide for the development of a graphical user interface. This task was funded by NASA Headquarters and will end in mid-December 1995. Lastly, a Lewis Research Center (LeRC) task to develop an Operations and Maintenance Cost Estimating Model for Space Station Microgravity Facilities was begun very late in the base contract year (November 13, 1995) and will extend four months into the Option Year 1 contract.

These additional tasks provide synergistic elements to each other as well as to the basic MSFC effort. Additionally, they often draw upon the data contained in the REDSTAR and NASCOM data bases, utilize the NASCOM Cost Model, and tailor the cost modeling methodologies developed under the basic contract to their needs so that uniform, compatible, and cost effective products are obtained by all NASA customers. The specific work performed in each of these tasks during this contract year is described in the following paragraphs.

III. 1. Ground Operations Cost Model (GOCM)

Under the previous contract, SAIC completely reworked the old GOCM that had been developed for the NASA Kennedy Space Center (KSC) by another contractor. The model was reprogrammed by SAIC as a menu-driven spreadsheet model that estimates facilities, schedules, manpower and costs at many levels and provides reporting, charting, supporting data bases, and documentation. It will estimate up to two different type vehicles in flow at the launch site, and estimate ground operations cost of over 80 different combinations of current and future launch vehicle elements including expendable, partially reusable, and reusable concepts. The model was delivered under the previous contract and has been in use at KSC since then.

This contract year, SAIC converted the entire model to Excel 5.0. A new-ways-of-doing-business (NWODB) section was structured, validated, and added to the model. This section provides the capability of adjusting for improvements in operating techniques and savings of up to 45% are possible under the appropriate assumptions. A new User's Guide was developed and delivered which included the Excel 5.0 changes, as well as the NWODB section, an updated Knowledge Base data base, and schedule update capability.

In addition, a Facility Modification Handbook was developed that references the existing model capability, expands current model definitions, provides new modification data, and provides new support equipment data.

III. 2. NASA Operations Cost Modeling

SAIC was tasked to begin a long range effort to develop a standardized operations cost model with common functional components supporting all centers. The current task involved scoping of the overall effort, establishment of an overall WBS which can be cross walked to each center unique operations, reviewing and assessing existing operations cost models for strengths and weakness, and beginning an operations cost data collection effort.

The operations capabilities, organizational structure, types of projects and capabilities of each NASA center involved in operations was studied. Additionally, each centers' plan to reduce cost or plan for "low cost" operations in the future was reviewed.

A Mission Operations Generic Function-Based WBS and definitions of terms was structured and mailed to the NASA centers for comment in mid-July. The WBS was also presented at the meeting of the NASA Operations Cost Model Development Steering Committee at GSFC on September 27. The generic WBS broke NASA Operations into two major elements, Launch Operations and Mission Operations.

Launch Operations concerns launch vehicle ground and launch support, recovery operations, refurbishment operations, launch facilities, sustaining engineering, and institutional support associated with launch operations (with detailed breakouts under each of these headings). Much of the effort in Launch Operations is currently captured in the SAIC-developed GOCM (see Paragraph III. 1.) cost estimating methodology, but a few non-KSC areas of responsibility still require cost model development.

Mission Operations encompasses manned spacecraft, and unmanned earth orbital and planetary spacecraft and payloads. This is a much more difficult area to capture in a standard WBS because of the many unique center requirements. SAIC's initial cut at this side of the WBS included utilization capability development, flight operations, sustaining mission operations, data processing, and institutional support. The detailed breakout under each of these heading has been modified to accommodate inputs from the various NASA users. SAIC provided a cross walk for each center from the generic WBS to their

organizational structure as an aid in their understanding of the proposed WBS.

Cost, programmatic, and technical operations data collection efforts during this contract year include Space Station, Space Station Furnace, Shuttle payloads, Free Flyers (HST, AXAF, XTE, GRO, and EUVE). Mission operations spacecraft resumes were constructed that detail operational information on each mission. In addition, technical data has been compiled that indicates probable operations cost drivers for use in CER development.

III. 3. CD-ROM Scanning Effort

SAIC was tasked with selecting approximately 2,500 key documents in the REDSTAR Data Base, scanning them, developing CD-ROMs with appropriate indexes and key word search capability, and delivering 10 sets of the CD-ROMs to various users throughout NASA. Many document-scanning equipment types were surveyed and the Canofile 510 System with various support items was selected. The equipment was purchased in May and became operational in June. The equipment has operated flawlessly from start-up through the end of the contract base year.

Approximately 2,200 documents (totaling over 280,000 pages) were scanned in this contract year from the following Special Collections: POP's, External Tank, SRM, Shuttle Performance, Schedules, Space Station, Cost Models, Lessons Learned, Launch Vehicle, Manned Spacecraft, Unmanned Spacecraft, and JSC Library. The remaining scanning and preparation of ten sets of the REDSTAR CD-ROM collection to distribute to the NASA Centers will be completed on schedule on January 31, 1996.

III. 4. Calibration of PRICE Systems Cost Model

SAIC was tasked to continue to support NASA Headquarters in calibrating the commercially available PRICE Cost Model for NASA users. This contract year SAIC has collected additional technical and programmatic data and normalized the data to PRICE's inputs. Most of the MCPLX and ECMPLX values at the subsystem level for the 93 NASA and Air Force projects in NASCOM have been calculated this year, although this task extends until January 31, 1996. By that time the PRICE input variables (WT/WS, VOL, DSTART, NEWST, and ECMPLX) and the calibrated complexities (MCPLXS) for each data point will have also been entered into NASCOM for release in the next NASCOM version.

A summary of this data will also be compiled into a calibration handbook and made available to NASA PRICE users. This data will allow PRICE users to generate an estimate of a new system by using the calibrated input data from an analogous data point or points. This simplified, subsystem level approach using NASCOM data for calibrating aerospace projects will be of great benefit to all NASA PRICE users.

III. 5. ARC Cost Analysis

SAIC was tasked to continue the development of the Automation Life Cycle Cost Model (ALCM) and to provide independent cost estimates to projects as requested. The first phase of this one year task is scheduled to be completed in April 1996. SAIC personnel spent several weeks at Ames Research Center to select an individual to serve as the on-site analyst, to train the analyst in SAIC's cost estimating methodologies, to insure that the customer needs were understood, and to iniate the task in a timely manner.

We completed a draft version of a project plan for the task which describes the planned enhancements for ALCM-Phase III, our expected accomplishments for this year in the cost estimating support area, and future work in the continued development of the ALCM. We developed an independent cost estimate and risk analysis for the Stratospheric Observatory For Infrared Astronomy (SOFIA). The Telescope Assembly, Console & Electronics System (CES), and the Data Managment, Acquisition, and Communication System (DMACS) portions of SOFIA were estimated. We assisted the Surface Movement Advisor (SMA) project in determining the facility cost for one year. SAIC provided the facility cost data from the Ground Operations Cost Model (GOCM) model which included costs for similar buildings at Kennedy Space Center (KSC).

We are currently developing an independent cost estimate and schedule including resources for the Surface Movement Advisor Development & Test. SMA is a NASA/FAA project that will help airports handle their air traffic more efficiently. The SDTF will be a full-scale air traffic control tower simulator built in an existing high bay at Ames. We are working on the first step in identifying generic processes for use in the continuing development of the Automation Life Cycle Cost Model (ALCM). We are organizing five spacecraft mission data bases into broad categories of processes. This work will continue through April 1996.

III. 6. Graphic User Interface Displays

This task was to develop six graphical user interface pages for use on the World Wide Web. These pages, or screens, provide a logical flow of images that indicate to the users their current location within the framework. Within the images are messages developed in hypertext mark up language that can be accessed to provide additional information. SAIC developed both the comprehensive graphics and the hypertext links for this effort. While this task is basically complete, some small effort will extend a week or two into the Option Year 1 period.

III. 7. LeRC Microgravity Operations Cost Modeling

This task began during the last two weeks of the base year contract. It involves the development of an automated tool for LeRC to be used for estimating the operations and maintenance costs of Space Station Microgravity instruments support facilities. Effort in this contract year consists primarily of scoping the overall task and laying out a schedule for its accomplishment.